MULTI-ROLLER BALL FOR CONSTANT VELOCITY JOINTS

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CROSS-REFERENCE TO RELATED APPLICATIONS

U.S. Patent Documents

U.S. Pat. No. 2,046,584 filed July 1924 by A. H. Rzeppa

U.S. Pat. No. 3,879,960, filed July 1975 by H. Welschof et al

U.S. Pat. No. 2,322,570 filed June 1943 by A. Y. Dodge

U.S. Pat. No. 1,975,758 filed October 1934 by B. K. Stuber

Other References

"Universal Joint and Driveshaft Design Manual," The Society of Automotive Engineers, Inc. 400 Commonwealth Drive, Warrendale, PA 15096, ISBN 0-89883-007-9, 1979.

Philip J. Mazziotti, "Dynamic Characteristics of Truck Driveline Systems," The Eleventh L. Ray Buckendale Lecture, SP 262, The Society of Automotive Engineers, Inc..

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the torque-transmitting balls for the constant velocity joints. In particular, the invention relates to a multi-roller ball in the form of a sphere divided up into a plurality of rollers (rolling elements) and a common shaft that holds the rollers. The purpose of the invention is to reduce the friction loss and wear of the constant velocity joints.

2. Description of the Prior Art

Universal joints (Cardan joint or Hooke joint) have been used for transmitting a driving torque and spin motion from one propeller shaft to another at an arbitrary articulation (joint)

angle between the two shafts. Universal joints comprise a cross-shaped spider as a torque-transmitting member, and two Y-shaped end yokes each at end of the shafts. Universal joints lack the constant-velocity characteristic, because the spider is not positioned on a homokinetic plane (bisecting angle plane or constant velocity plane) when the joint is at a non-zero articulation angle. As a result, universal joints suffer from a torsional vibration problem that aggravates as the articulation angle increases.

Constant velocity joints solve this problem by offering a virtually zero variation of the spin speed across the input and output shafts. Most of the constant velocity joints use a plurality of torque-transmitting balls that are solid steel spheres. The types of the constant velocity joints that use torque-transmitting balls are the Rzeppa joint [U.S. Pat. No. 2,046,584 filed July 1924 by A. H. Rzeppa], the undercut free joint [U.S. Pat. No. 3,879,960, filed July 1975 by H. Welschof et al], the cross groove joint [U.S. Pat. No. 2,322,570 filed June 1943 by A. Y. Dodge], and the double offset joint [U.S. Pat. No. 1,975,758 filed October 1934 by B. K. Stuber]. Any type of constant velocity joint comprises the inner race (inner joint part), outer race (outer joint part), ball cage (retainer) and the balls. The outer race usually forms a bell-shaped member that comprises a shaft, a base, an aperture and outer ball grooves (tracks) that are machined on its bore surface. The inner race forms a hub that comprises a shaft and inner ball grooves that are machined on its outer surface. The ball cage is positioned between the outer race and the inner race, and comprises circumferentially distributed cage windows (pockets) that hold the balls in the central plane of the ball cage. The inner and outer groove pairs form a special kinematic arrangement that steers (drives) the balls to the homokinetic plane.

But constant velocity joints suffer from five distinct disadvantages: 1) they lose some amount of power to sliding friction; 2) the frictional heat could produce high temperature; 3) this high temperature limits the permissible operating speeds and loads; 4) the friction decreases the durability and life of the joints; and 5) the friction, when coupled with a certain operating condition, could lead to a binding (friction lock) problem. See for example, "Universal Joint and Driveshaft Design Manual," The Society of Automotive Engineers, Inc. 400 Commonwealth Drive, Warrendale, PA 15096, ISBN 0-89883-007-9, 1979, pp. 100; and Philip J. Mazziotti, "Dynamic Characteristics of Truck Driveline Systems," The Eleventh L. Ray Buckendale Lecture, The Society of Automotive Engineers, Inc., SP 262, pp. 21.

From the viewpoint of kinematics, the balls of a constant velocity joint cannot have a true rolling condition, because the grooves are not concentric and generally intersect each other. From the viewpoint of dynamics, each ball is steered (located) to the homokinetic plane by the combined action of an inner groove, an outer groove and a cage window. This means that there are at least three contact points on a ball, when a constant velocity joint is spinning under some torque load: the ball to inner groove contact, the ball to outer groove contact, and the ball to cage window contact. Obviously, the ball cannot retain a true rolling condition at all three contact points at the same time. Therefore, some or all of the contact points on a ball cannot but undergo a sliding contact or friction.

Previous attempts by others to reduce the friction problem of constant velocity joints have employed special lubricant. These attempts, however, have not proven to completely solve the friction problem, because such measure can only reduce the friction coefficient value.

BRIEF SUMMARY OF THE INVENTION

It is an object of the present invention to provide torque-transmitting balls for constant velocity joints, while reducing or eliminating the sliding friction of the balls against the surfaces of its mating inner groove, outer groove, and the cage window.

The present invention for a "multi-roller" ball provides the foregoing object, and thus offers significant improvements over the prior art. As its name implies, the multi-roller ball has a plurality of rollers, each of which contacts and rolls independently on its mating outer groove, inner groove and the cage window, respectively. None has embodied the concept of the multi-roller ball to cause its each roller to roll independent from each other, and thus to cause the reduction or elimination of the sliding friction problem in constant velocity joints.

The multi-roller ball offers the advantages of enabling any ball-type constant velocity joints to have a reduced internal friction loss; to have a smooth articulation and plunge; to have a lower operating temperature; to have an increased durability and life; and to have a higher operating speed and larger torque capacity.

The multi-roller ball enjoys these advantages because it has a plurality of sub-rollers rotating independently from each other around a common shaft called the roller shaft. Therefore, in a constant velocity joint receiving a torque load, one sub-roller can roll freely on an outer groove, while another sub-roller rolls on an inner groove, and the other sub-roller rolls on a cage window. This multi-roller construction relieves the ball assembly from a harmful sliding friction at its rolling contact points. In order to maintain the orientation of the roller shaft along the tangent direction of the cage circumference, a sliding pin is provided in such a manner that it can slide along the shaft hole through the axis of the roller shaft and that the both ends of the sliding pin ride within the cage-web slots that are machined at either sides of the cage webs towards the radial direction. Thus, the multi-roller ball achieves the implementation of the objectives mentioned above in a commercially viable component that is simple and inexpensive enough to be easily applicable to any existing ball-type constant velocity joints.

Further objectives and advantages of the multi-roller ball will become apparent from consideration of the drawings and descriptions that follow. Therefore, to the accomplishment of the objectives described above, this invention consists of the features hereinafter illustrated in the drawings, fully described in the detailed description of the preferred embodiments and particularly pointed out in the claims. However, such drawings and descriptions disclose but some of the various ways in which the invention may be practiced.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

FIG. 1 is a perspective view of a prior-art constant velocity joint.

FIG. 2 shows a prior-art constant velocity joint under a torque load in a partially enlarged central plane section, illustrating the contact points of a ball against the inner and outer grooves.

FIG. 3 is a partially enlarged radial view of a prior-art constant velocity joint, showing the contact between the ball and the cage window (the outer and inner races are not shown).

FIG. 4 shows the front view of a multi-roller ball in a first embodiment, illustrating the assembly of the center roller, two half-spherical rollers, the roller shaft, and the sliding pin.

FIG. 5 shows a multi-roller ball in a longitudinal (spin-axis) section, revealing the bearing surfaces between the components.

FIG. 6A and 6B are the front and side views of the half-spherical roller.

FIG. 7A and 7B are the front and side views of the roller shaft.

FIG. 8 shows an actual use of a multi-roller ball in a constant velocity joint in a partially enlarged central plane section, revealing the contact points of the half-spherical rollers against the inner and outer grooves.

FIG. 9 shows a partially enlarged radial view of my invention in an actual use with a constant velocity joint (the outer and inner races are not shown), revealing the contacts between the multi-roller ball and the cage.

FIG. 10 is a cross sectional view of the multi-roller ball in a second embodiment, taken in the spin-axis plane, showing the disc shaft that combines the roller shaft and the center roller.

FIG. 11 is a cross sectional view of the multi-roller ball in a third embodiment, taken in the spin-axis plane, showing the lug shaft that replaces the roller shaft and the sliding pin.

FIG. 12 is a cross sectional view of the multi-roller ball in a fourth embodiment, taken in the spin-axis plane, showing the half-spherical rollers that have a seat for the center roller.

FIG. 13 is a cross sectional view of the multi-roller ball in a fifth embodiment, taken in the spin-axis plane, showing the simplified embodiment that does not have the center roller and has only three major parts.

DETAILED DESCRIPTION OF THE INVENTION

Referring to the drawings, where like parts are designated throughout with like numerals and symbols, FIGS. 1 through 3 depict a prior art constant velocity joint, presented herein as an illustration of its general construction and inherent problem. A constant velocity joint comprises the outer race 1, the inner race 2, the cage (retainer) 4, and the balls 3. The outer race shaft 5 is either integral to the outer race 1, or securely connected to the outer race 1 by bolts or splines. The inner-race shaft 6 is typically connected to the inner race 2 by splines and retaining rings. The outer race 1 has a plurality of ball grooves 1a machined on its bore surface, while the inner race 2 has the pairing set of ball grooves 2a machined on its outer circumference surface. The positions of the balls 3 are restrained by the outer grooves 1a and the inner grooves 2a. The cage 4 has a plurality of the windows (pockets) 4a that hold the balls 3 so that all of the balls 3 are located on the central plane of the cage 4. The combined actions of the outer grooves 1a, the inner grooves 2a and the cage windows 4a steer (locate) the balls 3 towards the constant velocity

plane (bisecting-angle plane or homokinetic plane), yielding a constant velocity characteristics at any joint articulation angle.

FIG. 2 shows a partially enlarged central-plane section of a prior-art constant velocity joint that is receiving an external torque load 7, 8. The driving torque 7 onto the outer race 1 tries to rotate it to the counter-clock-wise direction, while the reaction torque load 8 onto the inner race 2 tries to rotate it to the clock-wise direction, resisting against the motion of the outer race 1. This action and reaction produce the contact forces 9, 10 onto the ball 3. The contact force 9 from the outer groove 1a to the ball 3 and another contact force 10 from and the inner groove 2a to ball 3 squeeze the ball 3. Thus each ball 3 has at least two contact points against its mating inner groove 2a and the outer groove 1a.

FIG. 3 is a partially enlarged radial view of a prior-art constant velocity joint, showing the contact condition between the cage 4 and the ball 3. Note that the outer race 1 and the inner race 2 are omitted in FIG. 3. Typically a cage 4 has a shape of two rings that are bridged together by the cage webs 4d. In FIG. 3, the cage window 4a is oriented such that its radial direction 12c is out-of-paper direction, its tangential or circumferential direction 12a is to the right-hand side, and its axial direction 12b is parallel to the cage axis 13. Each cage window 4a has two cage flat surfaces 4e, 4f and another two web flat surfaces 4g, 4h. The distance between the two cage-flat surfaces 4e, 4f are generally called the window width. The window width is typically designed to be equal to or slightly larger than the diameter of the ball 3. One of the main functions of the cage 4 is to push the ball 3 towards the homokinetic plane by generating the contact force 11 against the ball 3. Thus at any given moment, a ball 3 has at least one contact point against one of the cage flat surfaces 4e and 4f. The distance between the two opposing web flat surfaces 4g, 4h are generally called the window length. The window length is typically designed to have an enough gap from the ball 3 in order to accommodate any circumferential movement of the balls 3 during the joint articulation.

Therefore, each ball 3 of a prior-art constant velocity joint has at least three contact points (forces): The first contact point is against the outer groove 1a, the second one is against the inner groove 2a, and the third one is against the cage window 4a (in other words, the cage flat 4e or 4f). As a result, it is inevitable that the ball 3 undergoes a sliding friction at some or all of the

three contact points as the ball 3 is steered to another position. It is well known that this sliding friction could produce many problems such as the friction loss and the friction lock (binding), which could result in the heat generation and eventually the failure of the joint (durability problem). The goal of this invention is to prevent or reduce the friction-induced problems of the conventional ball-type constant velocity joints. This invention solves the problem by replacing the solid balls 3 with the multi-roller balls 20 that make the three contact points of each ball be independent from each other, thus positively eliminating the sliding friction.

FIG. 4 shows the front view of a multi-roller ball 20 in its first embodiment, illustrating the assembled state of its components, and FIG. 5 shows the longitudinal (spin-axis) section of the multi-roller ball 20, revealing the interfaces between the components. A multi-roller ball 20 comprises the center roller 21, two half-spherical rollers 22, 23, the roller shaft 24, and the sliding pin 25. In addition to these key components, a radial (sliding or needle) bearing 26 for the center roller 21 and another (sliding or needle) bearings 27, 28 for the half-spherical rollers 22, 23 may be optionally employed for the enhanced performance. Likewise, two retaining rings 29, 30 may be employed at the either ends of the roller shaft 24 to hold the components together, facilitating the assembly of the multi-roller balls 20 into a constant velocity joint. The center roller 21 can spin around and slide along the roller shaft 24 via the bearing 26. The center roller 21contacts and rolls on the cage flat surface 4e or 4f of the cage 4. The half-spherical rollers 22, 23 can spin individually around the roller shaft 24 via the bearings 27, 28, allowing them to contact and freely roll on the outer groove 1a or the inner groove 2a of a constant velocity joint. The roller shaft 24 serves as a spindle for the sub-rollers 21, 22, 23, and the hole along its axis serves as a sliding guide for the sliding pin 25. The sliding pin 25 maintains the spin axis orientation of the multi-roller ball 20 relative to the cage window 4a by constraining its two ends at the cage 4 as will be explained further in FIG. 8 and 9. In addition, the sliding pin 25 allows the roller shaft 24 to slide longitudinally so that the circumferential movement of the multi-roller ball 20 relative to the cage window 4a is accommodated. Since a multi-roller ball 20 has a plurality of sub-rollers 21, 22, 23 that spin independently from each other, it can positively eliminate or reduce any frictional sliding contact against the outer groove 1a, the inner groove 2a and the cage flat surface 4e or 4f.

FIGS. 6A and 6B show the front and side views of the half-spherical roller 22 or 23. Its center hole 22a that comprises the cylindrical bore surface 22b and the tapered bore surface 22c rides on the roller shaft 24 via the bearing 27 or 28. The spherical surface 22d contacts against the outer race grooves 1a or inner race grooves 2a. The inner flat surface 22e limits the axial movement of the center roller 21. The outer flat surface 22f is intended for shortening the axial length (except the sliding pin 25) of the multi-roller ball assembly 20 so that the length of the cage window (the distance between 4g and 4h) can be designed to be shorter. The outer flat surface 14f can also serve as a thrust surface against the retaining rings 29, 30.

FIGS. 7A and 7B show the front and side views of the roller shaft 24. Its cylindrical shaft surface 24a and the tapered surface 24b mate onto the bearings 27, 28 or directly onto the half-spherical rollers 22, 23. The cylindrical center surface 24c mates onto the bearings 26 or directly onto the center roller 21. The axial-drill hole 24d is for the sliding pin 25 that can freely spin within or move along the axial-drill hole 24d. The candidate materials for the roller shaft 24 are a solid metal, an oil-impregnated sintered metal, or any other sliding bearing material

FIG. 8 shows an actual use of a multi-roller ball 20 in a constant velocity joint in a partially enlarged central plane section, revealing the contact point of the half-spherical rollers 22, 23 against the inner and outer grooves 1a and 2a. The multi-roller balls 20 can be used in conjunction with any type of constant velocity joint, except that the cage 4 should have additional cage web slots 4i machined to radial direction at each web flat surfaces 4g and 4h. The cage web slots 4i mate with the ends of the sliding pin 25, constraining the orientation of each multi-roller ball assembly 20 with respect to the corresponding cage window 4a. For most of the ball-type constant velocity joints, the inner and outer ends of cage web slots 4i are blocked by the outer race bore surface 1b and the inner race outer surface 2c. Therefore, the ends of the sliding pin 25 cannot disengage from the cage web slots 4i. However, in the case of the cross groove type constant velocity joints, the cage bore side of the cage web slots 4i should be closed so that the ends of the sliding pin 25 do not fall to the gap between the cage bore surface 4b and the inner race outer surface 2c.

FIG. 9 shows a partially enlarged radial view of my invention in actual use with a constant velocity joint (the outer race 1 and inner race 2 are not shown here), revealing the

contacts between the multi-roller ball 20 and the cage 4. As the cage 4 steers the multi-roller ball 20, the center roller 21 contact against and rolls on the cage flat surface 4e or 4f. The either ends of the sliding pin 25 are restrained by the cage web slots 4i. Therefore, not only the center roller 21 but also the sliding pin 25 can take the steering force from the cage 4. If the center roller 21 to cage window 4a gap (clearance) and the sliding pin 25 to cage web slot 4i gap are about the same, then both the center roller 21 and the sliding pin 25 will take the steering force from the cage 4. If the center roller 21 to cage window 4a gap is smaller than the sliding pin 25 to cage web slot 4i gap, then the center roller 21 will take most of the steering force from the cage 4. Finally, if the center roller 21 to cage window 4a gap is larger than the sliding pin 25 to cage web slot 4i gap, then the sliding pin 25 will take most of the steering force from the cage 4, making the center roller 21 redundant.

FIG. 10 is a cross sectional view of the multi-roller ball 20 in a second embodiment, taken in the spin-axis 31 plane, showing the disc shaft 32 that combines the roller shaft 24 and the center roller 21 into a single solid part. The disc shaft 32 has the shape of a disc mounted at the middle of a cylindrical shaft. The disc portion of the disc shaft 32 functions not only as a center roller but also as a thrust load bearing surface for the half-spherical rollers 22, 23. The shaft portion of the disc shaft 32 serves as a shaft for the half-spherical rollers 22, 23. The thrust (sliding or needle) bearings 33, 34 may be optionally employed at the interfaces between the half-spherical rollers 22, 23 and the disc portion of the disc shaft 32. Likewise, the radial (sliding or needle) bearings 27, 28 may be optionally employed at the interfaces between the half-spherical rollers 22, 23 and the shaft portion of the disc shaft 32. The radial and thrust sliding bearing pairs (27, 33) and (28, 34) may be manufactured to be integral parts in the shape of flanged tube. In addition, two retaining rings 29, 30 may be employed at the either ends of the roller shaft 24 to hold the components together, facilitating the assembly of the multi-roller balls 20 into a constant velocity joint.

FIG. 11 is a cross sectional view of the multi-roller ball 20 in a third embodiment, taken in the spin-axis 31 plane. The lug shaft 35 is a modified version of the sliding pin 25 such that its sliding body 35a has a larger diameter and its two ends taper down forming the smaller diameter lugs 35b, 35c. The two lugs 35a, 35b of the lug shaft 35 mate into the cage web slots 4i. The roller shaft 24 has two tapered outer surfaces on which the half-spherical rollers 22, 23

ride. The center roller 21 rides on the cylindrical ridge between the two tapered portions of the roller shaft 24. The cylindrical bore surface of the roller shaft 24 interfaces onto the lug shaft 35. The roller shaft 24 can be made of any sliding-bearing materials such as the oil-impregnated sintered metal or the copper-based metal with solid lubricant inserts. However, additional needle bearings 26, 27, 28 may be employed at the interface between the roller shaft 24 and the sub-rollers 21, 22, 23. In addition, two retaining rings 29, 30 may be employed at the either ends of the roller shaft 24 to hold the components together, facilitating the assembly of the multi-roller balls 20 into a constant velocity joint.

FIG. 12 is a cross sectional view of the multi-roller ball 20 in a fourth embodiment, taken in the spin-axis 31 plane. This embodiment is a variation of the third embodiment such that the half-spherical rollers 22a, 23a have the roller seats 22g, 23g that accommodate the center roller 21. The sliding or needle bearings 26, 27, 28 can be optionally employed for the sub-rollers 21, 22, 23. In addition, two retaining rings 29, 30 may be employed at the either ends of the roller shaft 24 to hold the components together, facilitating the assembly of the multi-roller balls 20 into a constant velocity joint.

FIG. 13 is a cross sectional view of the multi-roller ball 20 in a fifth embodiment, taken in the spin-axis 31 plane. This simplified embodiment has only three major parts: two half-spherical rollers 22, 23 and the lug shaft 35. It should be noted that this fifth embodiment does not have a center roller 21. Therefore, this embodiment takes all the axial forces from the cage 4 at the two lugs 35b and 35c of the lug shaft 35. This simple structure of the fifth embodiment of the multi-roller ball 20 makes it economically feasible as a replacement for the conventional solid balls 3 of a constant velocity joints. The bearings 26, 27, 28 may be optionally employed at the interfaces between the three major parts. In addition, two retaining rings 29, 30 may be employed at the either ends of the roller shaft 24 to hold the components together, facilitating the assembly of the multi-roller balls 20 into a constant velocity joint.

From the foregoing it will be apparent that an apparatus and method have been disclosed which are fully capable of carrying out and accomplishing all of the objects and advantages taught by this invention. As many as possible embodiments may be made of the invention without departing from the scope thereof, it is to be understood that all matter herein set forth or

shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense. It will be understood that certain features and sub-combinations are of utility and may be employed without reference to other features and sub-combinations. This is contemplated by and is within the scope of the claims.